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WELDING OF AEROSPACE GROUND SUPPORT EQUIPMENT AND RELATED FACILITIES, SPECIFICATION FOR

LOGISTICS OPERATIONS DIRECTORATE

National Aeronautics and
Space Administration

John F. Kennedy Space Center

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APPROVED:

Original Signed By:
John R. Lyon
Director of Logistics Operations

JOHN F. KENNEDY SPACE CENTER, NASA

P2/MACW/KSC-0020

TABLE OF CONTENTS

Section	Title	Page
1.	SCOPE AND APPLICABILITY	1
1.1	Weld Classifications	1
1.1.1	Structural Welding Design	1
1.1.2	Structural Welding Inspection	1
1.1.3	Crane and Other Material Handling Equipment Weld Design and Inspection	2
1.1.4	Piping and Tubing Design and Inspection	2
1.1.4.1	Normal Fluid Service	2
1.1.4.2	Severe Cyclic Conditions	2
1.1.4.3	Category M Fluid Service	2
1.1.4.4	High-Pressure Fluid Service	2
1.1.4.5	Category D Fluid Service	2
1.1.5	Pressure Vessels	2
1.2	Classification of Weld Reinspection	2
2.	APPLICABLE DOCUMENTS	2
2.1	Governmental	3
2.1.1	Specifications	3
2.1.2	Directives	3
2.2	Non-Governmental	3
3.	REQUIREMENTS	5
3.1	General	5
3.2	Equipment	5
3.3	Materials	5
3.3.1	Material Certification	5
3.3.2	Base Metals	6
3.3.2.1	Structural Welding	6
3.3.2.2	Crane and Other Material Handling Equipment Welding	6
3.3.2.3	Piping and Tubing Welding	6
3.3.2.4	Pressure Vessels	6
3.3.3	Filler Metals	6
3.3.3.1	Structural Welding	6
3.3.3.2	Crane and Other Material Handling Equipment Welding	6
3.3.3.3	Piping and Tubing Welding	6
3.3.3.4	Pressure Vessels	6
3.3.3.5	Dissimilar Metal Welding	6
3.3.4	Consumable Inserts	6
3.3.5	Backing Rings	6
3.3.6	Tungsten Electrodes	6
3.3.7	Shielding Gases	6
3.3.8	Purging Gases	11
3.3.9	Antispatter Compounds	11

TABLE OF CONTENTS (cont)

Section	Title	Page
3.4	Welding Procedure and Welder/Welding Operator Performance Qualifications	11
3.4.1	Welding Procedure Qualification	11
3.4.2	Welder/Welding Operator Performance Qualification	11
3.5	Preweld Operations	11
3.5.1	Cleaning Requirements	11
3.5.2	Cleaning Technique	12
3.6	Production Welding	12
3.6.1	Preheating and Interpass Heating	12
3.6.1.1	Carbon Steel and Low Alloy Steel	12
3.6.1.2	Stainless Steel and Nickel Alloys	12
3.6.1.3	Aluminum Alloys	12
3.6.2	Use of Purging Gas	12
3.6.3	Tack Welds	13
3.6.4	Weld Bead Initiation and Termination	13
3.6.5	Back Gouging	13
3.6.6	Identification of Welds	13
3.6.7	Postweld Heating	13
3.6.7.1	Carbon Steel and Low Alloy Steel	13
3.6.7.2	Stainless Steel and Nickel Alloys	13
3.6.7.3	Aluminum Alloys	13
3.6.8	Postweld Cleaning	13
3.6.9	Inspection of Welds	13
3.6.9.1	Visual Inspection Acceptance Criteria	14
3.6.9.2	NDT Acceptance Criteria	14
3.6.10	Welding Repairs	14
3.6.10.1	Defect Removal	14
3.6.10.2	Repair Procedure	14
3.6.10.3	Repair Records	14
4.	QUALITY ASSURANCE PROVISIONS	14
4.1	Inspection and Testing	14
4.1.1	Responsibility for Inspection and Testing	14
4.1.2	Additional Inspection and Testing	14
4.2	Certified Welding Inspector (CWI)	15
4.3	Qualification of NDT Personnel	15
4.4	Preweld and Welding Inspection	15
4.5	Postweld Inspection	15
4.5.1	Visual Inspection	15
4.5.1.1	Structural Welds	15
4.5.1.2	Crane and Other Material Handling Equipment Welds	15
4.5.1.3	Piping and Tubing Welds	16
4.5.1.4	Pressure Vessels	16
4.5.2	Nondestructive Testing	16
4.5.2.1	Structural Welds	16

TABLE OF CONTENTS (cont)

Section	Title	Page
4.5.2.1.1	Class A Inspection	16
4.5.2.1.2	Class B Inspection	16
4.5.2.1.3	Class C Inspection	16
4.5.2.2	Crane and Other Material Handling Equipment Welds	16
4.5.2.2.1	Primary Welds (Class A)	16
4.5.2.2.2	Secondary Welds (Class B)	16
4.5.2.2.3	Secondary Welds (Class C)	16
4.5.2.3	Piping and Tubing Welds	17
4.5.2.3.1	Normal Fluid Service	17
4.5.2.3.2	Severe Cyclic Conditions	17
4.5.2.3.3	Category M Fluid Service	17
4.5.2.3.4	High-Pressure Fluid Service	17
4.5.2.3.5	Category D Fluid Service	17
4.5.2.3.6	In-Process Examination for Automatic Gas Tungsten Arc Welding (GTAW)	17
4.5.2.4	Pressure Vessels	18
4.5.2.5	Alternate NDT Methods	18
4.5.2.6	Etching for PT	18
4.5.3	Inspection Records	18
5.	PREPARATION FOR DELIVERY	18
6.	NOTES	18
6.1	Intended Use	18
6.2	Data Required in Design Documentation	19
6.3	Definitions	19
APPENDIX A	RECOMMENDED ANSI/AWS PUBLICATIONS	A-1

LIST OF TABLES

Table	Title	Page
1	Allowable Stainless Steel Base Metal and Filler Metal Combinations	7
2	Allowable Nickel Alloy Base Metal and Filler Metal Combinations	8
3	Filler Metal Requirements for Aluminum Piping and Tubing	9
4	Modified Invar 36 Filler Metal Composition	10
5	Recommended Filler Metal Requirements for Selected Dissimilar Metal Combinations	10
6	Shielding and Purging Gases	11

ABBREVIATIONS AND ACRONYMS

AA	Aluminum Association
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
AWS	American Welding Society
BPVC	Boiler and Pressure Vessel Codes
^{o}C	degree Celsius
CO_2	carbon dioxide
CWI	certified welding inspector
e.g.	for example
etc.	et cetera
^{o}F	degree Fahrenheit
GTAW	gas tungsten arc welding
i.e.	that is
MIL	military
mm	millimeter
MT	magnetic particle testing
NASA	National Aeronautics and Space Administration
NDT	nondestructive testing
NHB	NASA handbook
NMI	NASA management instruction
PQR	procedure qualification record
PT	penetrant testing
rpm	revolutions per minute
RT	radiographic testing
UNS	Unified Numbering System
U.S.P.	United States Pharmacopoeia
WPQ	welder performance qualification
WPS	welding procedure specification

WELDING OF AEROSPACE GROUND SUPPORT EQUIPMENT AND RELATED FACILITIES, SPECIFICATION FOR

1. SCOPE AND APPLICABILITY

This specification establishes the minimum requirements for qualifying welders, welding operators, and welding procedures for the fabrication, repair, and inspection of manual, semiautomatic, and automatic welds in aerospace ground support equipment and related facilities used by or for the John F. Kennedy Space Center (KSC). This specification applies to the design, fabrication, inspection, and maintenance of aerospace ground support equipment and facilities used to support the operations of transporting, receiving, handling, assembly, inspection, test, checkout, service, and launch of space vehicles and payloads.

The current revision of this specification shall be applicable to the design, fabrication, inspection, and maintenance of all ground support equipment and related facilities. The revision of this specification that was current at the time direction was issued to design, construct, manufacture, or procure the ground support equipment or facility shall be applicable for the useful life of the hardware. Modifications and repair of existing hardware may be done so the modified/repaired hardware complies with the revision that is current at the time directions are issued to modify the hardware.

The requirements of this specification shall not be imposed on ground support equipment for class C and D payloads and experiments as defined by NMI 8010.1.

This specification applies to facility, systems, and equipment projects accomplished by KSC or KSC contractor personnel to the extent specified in their contracts.

NOTE

Contractors are responsible for the strict adherence of their subcontractors to the requirements of this specification.

1.1 Weld Classifications. - The classifications defined in the following paragraphs shall be used by the design engineer to establish design and inspection requirements for all welds.

1.1.1 Structural Welding Design. - The design engineer shall specify whether the requirements [e.g., allowable weld stresses, nondestructive testing (NDT) acceptance criteria] of sections 8, 9, or 10 (Statically Loaded Structures, Dynamically Loaded Structures, or Tubular Structures, respectively) of the American National Standards Institute (ANSI)/American Welding Society (AWS) D1.1 or D1.2 apply to a given weldment. The design engineer shall identify the components to be welded as either conventional facilities (including equipment) or nonconventional facilities (including equipment) (see 6.3). Unless otherwise specified, the components to be welded shall be considered nonconventional facilities (including equipment).

1.1.2 Structural Welding Inspection. - The design engineer shall use the following classifications to establish levels of inspection for structural weldments:

a. Class A Inspection. - Applicable to those welds where failure would be catastrophic in effect and/or welds that are highly stressed and characterized as a single point of

failure with no redundancy for the redistribution of stress into another member. These welds shall meet the highest strength and quality requirements specified. Groove welds designated Class A should be complete joint penetration welds.

b. Class B Inspection. - Applicable to those welds where failure would reduce the overall efficiency of the system, but a loss of system or hazard to personnel would not be experienced.

c. Class C Inspection. - Applicable to those welds where failure would not affect the efficiency of the system nor create a hazard to personnel.

1.1.3 Crane and Other Material Handling Equipment Weld Design and Inspection. - The design engineer shall classify all welds as either primary or secondary, in accordance with ANSI/AWS D14.1. For the purposes of inspection, primary welds shall also be classified as Class A and secondary welds shall be classified as either Class B or Class C. The Class A, B, and C designations are analogous to the structural welding inspection classifications described in 1.1.2.

1.1.4 Piping and Tubing Design and Inspection. - The design engineer shall use the classifications indicated in the following paragraphs to establish design and inspection requirements for piping and tubing weldments:

1.1.4.1 Normal Fluid Service. - As defined in the American Society of Mechanical Engineers (ASME) B31.3.

1.1.4.2 Severe Cyclic Conditions. - As determined by the design engineer and in accordance with ASME B31.3.

1.1.4.3 Category M Fluid Service. - As defined by ASME B31.3. All welds in hypergol (defined as Type J fluid service in NHB 8060.1) systems shall be classified for category M fluid service.

1.1.4.4 High-Pressure Fluid Service. - As defined by ASME B31.3.

1.1.4.5 Category D Fluid Service. - As defined by ASME B31.3.

1.1.5 Pressure Vessels. - All design and inspection requirements shall be in accordance with ASME Boiler and Pressure Vessel Codes (BPVC), section VIII.

1.2 Classification of Weld Reinspection. - With the exception of reinspection of welds during the repair of fabrication defects (see 3.6.10), this specification does not cover the reinspection requirements (e.g., annual reinspections) of welds such as those required by operational or maintenance documents. This specification does not cover the identification of welds requiring such reinspections, often referred to as "critical welds." Identification of welds requiring such reinspection and the method of reinspection should be specified in the design documentation.

2. APPLICABLE DOCUMENTS

The following documents of the issue in effect on the date of invitation for bids or requests for proposals form a part of this document to the extent specified herein. When this document is used for procurement, including solicitations, or is added to an existing contract, the specific revision levels, amendments, and approval dates of said documents shall be specified in an attachment to

the Solicitation/Statement of Work/Contract. In the event of a conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Governmental.

2.1.1 Specifications.

Federal	
BB-C-101	Carbon Dioxide (CO_2): Technical and U.S.P.
BB-O-925	Oxygen, Technical, Gas and Liquid
Military	
MIL-A-18455	Argon, Technical
MIL-P-27407	Propellant Pressurizing Agent, Helium
MIL-H-6088	Heat Treatment of Aluminum Alloys
MIL-I-23413	Inserts, Welding, Filler Material, Coiled and Solid Rings

2.1.2 Directives.

National Aeronautics and Space Administration (NASA)	
NMI 8010.1	Classification of NASA Payloads
NHB 8060.1	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

2.2 Non-Governmental.

American Society of Mechanical Engineers (ASME)	
ASME B31.3	Chemical Plant and Petroleum Refinery Piping
ASME Boiler and Pressure Vessel Codes	
Section VIII	Rules for Construction of Pressure Vessels

(Applications for copies should be addressed to the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.)

American National Standards Institute (ANSI)/American Society for Nondestructive Testing (ASNT)

ANSI/ASNT CP-189	Standard for Qualification and Certification of Nondestructive Testing Personnel

(Applications for copies should be addressed to the American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228-0518.)

American National Standards Institute (ANSI)/American Welding Society (AWS)

ANSI/AWS A3.0	Standard Welding Terms and Definitions Including Terms for Brazing, Soldering, Thermal Spraying and Thermal Cutting
ANSI/AWS A5.4	Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding
ANSI/AWS A5.9	Specification for Bare Stainless Steel Welding Electrodes
ANSI/AWS A5.10	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
ANSI/AWS A5.11	Specification for Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding
ANSI/AWS A5.12	Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding and Cutting
ANSI/AWS A5.14	Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods
ANSI/AWS A5.22	Specification for Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes
ANSI/AWS A5.30	Specification for Consumable Inserts
ANSI/AWS D1.1	Structural Welding Code - Steel
ANSI/AWS D1.2	Structural Welding Code - Aluminum
ANSI/AWS D1.3	Structural Welding Code - Sheet Steel
ANSI/AWS D10.7	Recommended Practices for Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe
ANSI/AWS D14.1	Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment

ANSI/AWS QC 1 Standard for AWS Certification of Welding Inspectors

(Applications for copies should be addressed to the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135.)

3. REQUIREMENTS

3.1 General. - Structural welding of carbon steel, low alloy steel, stainless steel and nickel alloys shall be in accordance with ANSI/AWS D1.1, and as specified herein. Structural welding of aluminum and aluminum alloys shall be in accordance with ANSI/AWS D1.2 and as specified herein. Structural welding of sheet steel shall be in accordance with ANSI/AWS D1.3 and as specified herein. Welding of cranes and other material handling equipment shall be in accordance with ANSI/AWS D14.1 and as specified herein. Welding of pressurized piping and tubing shall be in accordance with ASME B31.3 and as specified herein. Welding of pressure vessels shall be in accordance with ASME BPVC, section VIII and as specified herein. The necessary equipment, materials, qualified welders, welding operators, and procedures shall be provided by the contractor to meet the requirements of this specification. The contractor shall ensure adequate protection is provided for equipment and adjacent surfaces during welding operations. Damages resulting from failure to provide protection shall be repaired to the satisfaction of the the procuring agency or its designated representative at no additional cost to the Government.

NOTE

Welding procedure specifications (WPS's) for stainless steels and nickel alloys to be welded in accordance with ANSI/AWS D1.1 are never considered to be prequalified and must always be qualified by testing.

3.2 Equipment. - Automatic, semiautomatic, and manual welding shall be accomplished using equipment containing calibrated dials, meters, recorders, and/or computers that indicate welding parameters. All welding equipment shall be capable of producing welds that meet the requirements specified herein when operated by a qualified operator in accordance with a qualified welding procedure specification (WPS).

Measuring instruments, meters, gages, or direct reading electrical control circuits to be utilized for automatic, semiautomatic and manual welding operations shall be initially calibrated and periodically recalibrated at intervals not to exceed 6 months, or when any maintenance is performed that may have changed calibration.

3.3 Materials. - All welding materials shall be stored and handled so that no damage or degradation will result during storage and handling. Filler metals and inserts shall be handled and stored to prevent moisture contact and condensation. Filler metals and inserts that show signs of damage shall not be used. Storage methods for steel and low alloy steel covered, low-hydrogen shielded metal arc welding electrodes shall be in accordance with section 4.5 of ANSI/AWS D1.1.

3.3.1 Material Certification. - Prior to the start of production welding, the contractor shall ensure that all materials to be used (e.g., base metals, filler metals, etc.) conform to the appropriate specifications. A record (i.e., written documentation) of material certifications (e.g., results of any chemical analyses or mechanical testing, manufacturer's or heat treater's records, etc.) shall be maintained by the contractor and made available to the procuring agency.

3.3.2 Base Metals. - Unless otherwise specified or approved by the procuring agency, the base metals to be welded in accordance with this specification are as indicated in the following paragraphs.

3.3.2.1 Structural Welding. - Carbon steel and low alloy steels shall be in accordance with ANSI/AWS D1.1; aluminum alloys shall be in accordance with ANSI/AWS D1.2; sheet steel shall be in accordance with ANSI/AWS D1.3; stainless steels shall be in accordance with table 1; nickel alloys shall be in accordance with table 2.

3.3.2.2 Crane and Other Material Handling Equipment Welding. - All materials to be welded shall be in accordance with ANSI/AWS D14.1.

3.3.2.3 Piping and Tubing Welding. - All materials to be welded shall be in accordance with ASME B31.3 and table 3.

3.3.2.4 Pressure Vessels. - All materials to be welded shall be in accordance with ASME BPVC, section VIII.

3.3.3 Filler Metals. - Unless otherwise specified or approved by the procuring agency, all filler metals shall be as follows:

3.3.3.1 Structural Welding. - Filler metal selection for carbon steel and low alloy steel shall be in accordance with ANSI/AWS D1.1; filler metal selection for aluminum alloys shall be in accordance with ANSI/AWS D1.2; filler metal selection for sheet steel shall be in accordance with ANSI/AWS D1.3; filler metal selection for stainless steels shall be in accordance with table 1; filler metal selection for nickel alloys shall be in accordance with table 2.

3.3.3.2 Crane and Other Material Handling Equipment Welding. - Filler metal selection shall be in accordance with ANSI/AWS D14.1.

3.3.3.3 Piping and Tubing Welding. - Filler metal selection shall be in accordance with ASME B31.3 and as indicated in table 1 for stainless steel, table 2 for nickel alloys, and table 3 for aluminum alloys.

3.3.3.4 Pressure Vessels. - Filler material selection shall be in accordance with ASME BPVC, section VIII.

3.3.3.5 Dissimilar Metal Welding. - Recommended filler metals for the welding of selected dissimilar metal combinations are listed in table 5.

3.3.4 Consumable Inserts. - Consumable inserts shall be in accordance with ANSI/AWS A5.30 or MIL-I-23413. Consumable inserts shall be of the same nominal composition as the filler metal to be used.

3.3.5 Backing Rings. - With the exception of welds designated for Category D fluid service, backing rings shall not be used.

3.3.6 Tungsten Electrodes. - Tungsten electrodes shall be in accordance with ANSI/AWS A5.12.

3.3.7 Shielding Gases. - Shielding gases shall be in accordance with table 6.

Table 1. Allowable Stainless Steel Base Metal and Filler Metal Combinations(1)

Base Metal Alloy Designation	304L (S30403)	316L (S31603)	321 (S32100) 347(S34700)	Nitronic 33(2) (S24000)	Nitronic 40(2) (S21900 and S21904)
304L (S30403)	E308L ER308L E308LT-X E347 ER347 E347T-X				
316L (S31603)	E308L ER308L E308LT-X E347 ER347 E347T-X	E316L ER316L			
321 (S32100) 347 (S34700)	E308L ER308L E308LT-X E347 ER347 E347T-X	E347 ER347 E347T-X	E347 ER347 E347T-X ER321		
Nitronic 33(2) (S24000)	E308L ER308L E308LT-X	E308L ER308L E308LT-X	E347 ER347 E347T-X E308L ER308L E308LT-X	E209 ER209 E240 ER240 E308L ER308L E308LT-X	
Nitronic 40(2) (S21900 and S21904)	E308L ER308L E308LT-X	E308L ER308L E308LT-X	E347 ER347 E347T-X E308L ER308L E308LT-X	E209 ER209 E308L ER308L E308LT-X	E209 ER209 E219 ER219 E308L ER308L E308LT-X

Notes:

1. The left column and top row list the base metals. The remaining columns and rows list the filler metals to be used when matched to a combination of base metals. The base metals are listed by either their American Iron and Steel Institute classification or their trade name with their Unified Numbering System (UNS) designation in parentheses. The filler metals are listed by their AWS classifications in accordance with either ANSI/AWS A5.4, A5.9, or A5.22.

2. Welding Nitronic stainless steel with 308L filler metal will result in a joint with an ultimate tensile strength significantly less than that of a weld made with matching (Nitronic) filler metal. Where weldments greater than 6.35 millimeters (mm) (0.25 inch) are to be used in cryogenic applications, the use of 308L (if the lower strength is acceptable) or a nickel-based filler metal is recommended.

Table 2. Allowable Nickel Alloy Base Metal and Filler Metal Combinations

Base Metal	Filler Metal(s)
Invar 36	Modified Invar 36(2)
Hastelloy C-22 (N26022)	ENiCrMo-10 ERNiCrMo-10
Inconel 600 (N06600)	ERNiCr-3 ERNiCrFe-5
Inconel 718 (N07718)	ERNiFeCr-2
Monel K-500 (N05500)	ENiCu-7 ERNiCu-7

Notes: 1. The base metals are listed by their trade names with their UNS designations in parentheses. The filler metals are listed by their AWS classifications in accordance with either ANSI/AWS A5.11 or A5.14.

2. The chemical composition of Modified Invar 36 shall be in accordance with table 4.

Table 3. Filler Metal Requirements for Aluminum Piping and Tubing
(Reprinted from ANSI/AWS D10.7 with permission from the American Welding Society)

Base metal alloy designation	356.0 443.0	6061 6063 6101 6351	5454	514.0 5154 5254[a]	5086	5083	5052 5652[a]	3004	1100 3003 Alc 3003	1060 1350
1060, 1350	ER 4043[f]	ER 4043[b,f]	ER 5654[b]	ER 5654[b]	ER 5356[b]	ER 5356[b]	ER 5654[b]	ER 5654[b]	ER 1100[c]	ER 1100[c]
1100, 3003, Alc 3003	ER 4043[f]	ER 4043[b,f]	ER 5654[b]	ER 5654[b]	ER 5356[b]	ER 5356[b]	ER 5654[b]	ER 5654[b]	ER 1100[c]	
3004	ER 4043[f]	ER 5654[b,c]	ER 5654[b]	ER 5654[b]	ER 5356[b]	ER 5356[b]	ER 5654[b]	ER 5654[b]		
5052, 5652[a]	ER 4043[f]	ER 5654[b,c]	ER 5654[b]	ER 5654[b]	ER 5356[b]	ER 5356[b]	ER 5554[a,b]			
5083	ER 5356[b,c]	ER 5356[b]	ER 5356[b]	ER 5356[b]	ER 5356[e]	ER 5183[e]				
5086	ER 5356[b,c]	ER 5356[b]	ER 5356[b]	ER 5356[b]	ER 5356[e]					
514.0, 5154, 5254b	ER 4043[b,f]	ER 5654[b]	ER 5654[b]	ER 5654[a,b]						
5454	ER 4043[b,f]	ER 5654[b]	ER 5554[b]							
6061, 6063, 6101, 6351	ER 4043[b,f]	ER 5654[b]								
356.0, 443.0	ER 4043[b,f]									

Notes:

1. Recommendations in this Table apply to the gas shielded arc welding processes. For oxyacetylene gas welding, only ER 1100, ER4043, and ER4047 filler metals are ordinarily used.
2. Filler metals are listed in AWS Specification A5.10.
3. Filler metals ER5356, ER5183, ER5556, and ER5654 are not recommended for sustained elevated temperature service [over 65 °C (150 °F)]. ER5554 is suitable for elevated temperature service.
4. Local corrosion attack may occur in the weld region in certain electrolytes, due to solution potential variations. These variations can result from compositioned differences between the filler and base metals or from heat related metallurgical effects.

a. Base metal alloys 5254 and 5652 are used for hydrogen peroxide service. ER5654 filler metal is used for welding both alloys for service below 65 °C (150 °F).
b. ER5183, ER5356, ER5556, and ER5654 may be used. In some cases they provide (1) improved color match after an anodizing treatment, (2) higher weld ductility, and (3) higher weld strength. ER5554 is suitable for elevated temperature service.
c. ER4043 or ER4047 may be used.
d. Filler metal with the same analysis as the base metal can be used.
e. ER5183, ER5356, or ER5556 may be used.
f. ER4047 may be used.

Table 4. Modified Invar 36 Filler Metal Composition

Element	Percent
Nickel	35.0 to 36.5
Manganese	2.6 to 3.4
Titanium	0.7 to 1.3
Carbon	0.04 (maximum)
Silicon	0.30 (maximum)
Sulfur	0.008 (maximum)
Phosphorus	0.012 (maximum)
Iron	Remainder

Table 5. Recommended Filler Metals for Selected Dissimilar Metal Combinations

Base Metal	Carbon Steel and Low Alloy Steel	Austenitic (300-series) Stainless Steel	Invar 36	Hastelloy C-22	Inconel (600/718)	Monel K-500
Austenitic (300 series) Stainless Steel	ENiCrFe-2 ENiCrFe-3 ERNiCr-3 E312 ER312 E312T-X					
Invar 36		ERNiCr-3				
Hastelloy C-22	ENiCrMo-10 ERNiCrMo-10 ERNiCrMo-9	ENiCrMo-10 ERNiCrMo-10				
Inconel (600/718)	ENiCrFe-2 ENiCrFe-3 ERNiCr-3	ENiCrFe-2 ENiCrFe-3 ERNiCr-3				
Monel K-500	ENiCu-7 ERNi-1	ENiCrFe-2 ENiCrFe-3 ERNiCr-3			ENiCrFe-2 ENiCrFe-3 ERNiCr-3	

Note: The left column and top row list the base metals. The remaining columns and rows list the filler metals to be used when matched to a combination of base metals. The base metals are listed by either general classification or trade name; the filler metals are listed by their AWS classifications in accordance with ANSI/AWS A5.4, A5.9, A5.11, A5.14, or A5.22.

3.3.8 Purging Gases. - Purging gases shall be either argon, helium, or an argon-helium mixture as shown in table 6.

3.3.9 Antispatter Compounds. - Antispatter compounds shall not be used.

Table 6. Shielding and Purging Gases

Gas	Description and Percentage	Specification
Argon	Gas	MIL-A-18455
Carbon Dioxide	Grade B	BB-C-101
Helium	Type I, grade A	MIL-P-27407
Oxygen	Type I	BB-O-925
Argon-oxygen mixture	Argon plus 1 to 5 percent oxygen	NA
Argon-carbon dioxide mixture	Argon plus 20 to 50 percent carbon dioxide	NA
Argon-helium mixture	Any combination	NA

3.4 Welding Procedure and Welder/Welding Operator Performance Qualifications.

3.4.1 Welding Procedure Qualification. - Prior to the start of production welding, the contractor shall prepare a WPS for each weld to be made. Each WPS shall be prepared and qualified in accordance with ANSI/AWS D1.1, D1.2, D1.3, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable. A WPS is always required, even if the procedure is considered to be prequalified in accordance with ANSI/AWS D1.1 or D14.1, as applicable. The WPS and any resulting procedure qualification records (PQR's) shall record all required information on forms similar to or identical with those described in ANSI/AWS D1.1, D1.2, D1.3, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable. Copies of the WPS shall be available for reference by the welders, welding operators, and the procuring agency. The procuring agency reserves the right to require that all WPS's and PQR's be submitted for approval prior to the start of any production welding. The procuring agency shall be notified prior to any procedure qualification welding and/or testing with sufficient time to allow witnessing. The procuring agency reserves the right to witness all procedure qualification welding and/or testing.

3.4.2 Welder/Welding Operator Performance Qualification. - Prior to the start of production welding, each welder and welding operator shall be qualified in accordance with ANSI/AWS D1.1, D1.2, D1.3, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable. The resulting welder/welding operator performance qualification (WPQ) test records shall record all required information on forms similar to or identical with those described in ANSI/AWS D1.1, D1.2, D1.3, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable. Copies of the WPQ's shall be made available to the procuring agency. The procuring agency reserves the right to require that all WPQ's be submitted for approval prior to the start of any production welding. The procuring agency shall be notified prior to any performance qualification welding and/or testing with sufficient time to allow witnessing. The procuring agency reserves the right to witness all performance qualification welding and/or testing.

3.5 Preweld Operations.

3.5.1 Cleaning Requirements. - For the purposes of cleaning, the term "joint" shall be defined as the base metal surfaces to be welded, the adjacent base metal surfaces for a minimum of 50

millimeters (2 inches) on each side of those to be welded, any consumable inserts or backing, and all fixtures used in the vicinity of the weld. The joint shall be thoroughly cleaned prior to welding and kept clean during welding (e.g., by interpass cleaning in multipass welds). The joint and all filler metal shall be free of scale, slag, oil, grease, paint, low-melting temperature metals (e.g., lead, tin, cadmium), pencil or ink marks, oxides, and other contaminants. A cleaned joint shall not be touched by bare hands. Cleaning requirements shall be incorporated into the WPS (see 3.4.1).

3.5.2 Cleaning Technique. - All cleaning shall be performed before assembling the joints. Oils and greases shall be removed by solvent cleaning. Contaminated solvents shall not be used; solvents shall not be used after the joint is assembled. When wire brushing is performed, only clean, austenitic stainless steel wire brushes that have not been used on any other materials shall be used (e.g., a brush used to clean carbon steel shall not be used to clean stainless steel). When cleaning aluminum, solvent cleaning shall be followed by mechanical scraping; surfaces that are not welded within 4 hours shall be recleaned.

3.6 Production Welding.

3.6.1 Preheating and Interpass Heating. - Temperatures shall be measured by suitable temperature-indicating methods that are accurate within plus or minus 14 degrees Celsius (ºC) [25 degrees Fahrenheit (ºF)]. Heating and maintaining the proper temperature may be accomplished by any suitable method capable of providing a reasonably uniform temperature throughout the part. For field applications, it is preferred that induction coils or resistance heating braided "blankets" be used. When preheating is required, the joint shall be preheated prior to any welding, including tack welding.

3.6.1.1 Carbon Steel and Low Alloy Steel. - Preheating and interpass heating requirements shall be in accordance with ANSI/AWS D1.1, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable.

3.6.1.2 Stainless Steel and Nickel Alloys. - These materials shall not be preheated. The interpass temperature shall not exceed 93 ºC (200 ºF) at a maximum distance of 13 mm (0.5 inch) in all directions from the point of welding.

3.6.1.3 Aluminum Alloys. - Preheating is not usually recommended for aluminum alloys; however, if the base metal thickness is large and/or the ambient temperature is very low, preheating may be used. If preheating is used, the preheat temperature shall not exceed 93 ºC (200 ºF) at a maximum distance of 13 mm (0.5 inch) in all directions from the point of welding for Aluminum Association (AA) 5000-series aluminum alloys, and the holding time at this temperature shall not exceed 15 minutes. The maximum interpass temperature for AA 5000-series aluminum alloys shall not exceed 149 ºC (300 ºF) at a maximum distance of 13 mm (0.5 inch) in all directions from the point of welding. The maximum preheat and interpass temperatures for all other aluminum alloys shall be 177 ºC (350 ºF) at a maximum distance of 13 mm (0.5 inch) in all directions from the point of welding. Holding times at these temperatures should be minimized.

3.6.2 Use of Purging Gas. - Inert gas purging is required for all joints when consumable inserts are used. Inert gas purging is required for stainless steel, aluminum alloy, and nickel alloy joints with or without the use of consumable inserts. Inert gas purges shall be maintained for the root pass and subsequent passes until a minimum of 5 mm (0.2 inch) of weld metal has been deposited.

3.6.3 Tack Welds. - Tack welds shall be used as required and shall be made by a qualified welder or welding operator (see 3.4.2). Tack welds shall be spaced symmetrically around or along the joint whenever possible. Chipping or grinding shall be done to fair both ends of the tack weld in with the base metal. Tack welds that contain cracks or visible porosity shall not be fused with the root pass weld and shall be removed in accordance with 3.6.10.1.

3.6.4 Weld Bead Initiation and Termination. - Extension bars and runoff plates on which the welding arc can be started or extinguished shall be used whenever practicable. The initiation and termination points of each weld bead shall be chipped or ground as necessary to remove any visible defects in the weld metal before depositing any subsequent weld beads. The ground areas shall fair in with the adjacent base metal. No additional filler metal shall be added to a root pass when using a consumable insert. Weld beads should not terminate in critical (e.g., highly stressed) areas of the weld. Weld beads should not terminate in inside corners or in other critical areas such as changes in welding direction or sudden changes in section thickness.

3.6.5 Back Gouging. - All groove welded joints to be welded from both sides and require 100-percent penetration shall be back gouged to sound metal prior to the welding of the second side. Whenever possible, two or three passes shall be deposited on the first side prior to the gouging of the back side. Back gouging to sound metal may be done by chisel, grinder, or arc gouging. Gouged areas shall be smoothed to fair in with adjacent metal.

3.6.6 Identification of Welds. - Appropriate records shall be maintained that identify the welds made by each qualified welder and welding operator. These records shall be made available to the procuring agency. The actual weldments shall not be marked.

3.6.7 Postweld Heating. - Temperatures shall be measured by suitable temperature-indicating methods that are accurate within plus or minus 14 ^{o}C (25 ^{o}F). Heating and maintaining the proper temperature may be accomplished by any suitable method capable of providing a reasonably uniform temperature throughout the part. For field applications, it is preferred that induction coils or resistance heating braided "blankets" be used. If the entire weldment cannot be stress-relieved, then the minimum area to be heated to the required stress-relieving temperature shall be the same as the minimum area that would be required to be heated to preheating temperature.

3.6.7.1 Carbon Steel and Low Alloy Steel. - Stress-relief heat treatment requirements shall be in accordance with ANSI/AWS D1.1, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable.

3.6.7.2 Stainless Steel and Nickel Alloys. - Postweld heating of these materials is not permitted. If a postweld heat treatment of a precipitation-hardening stainless steel and/or nickel alloy is desired by the design engineer, these requirements shall be included in the design documentation.

3.6.7.3 Aluminum Alloys. - Unless otherwise specified or approved by the procuring agency, postweld heating of aluminum alloys is not permitted. When artificial aging of heat-treatable aluminum alloys is specified in the design documentation, such heat treatment shall be in accordance with MIL-H-6088.

3.6.8 Postweld Cleaning. - All welded assemblies shall be cleaned free of oxide, flux, scale, slag, or other foreign matter prior to the postweld inspections (see 4.5).

3.6.9 Inspection of Welds. - All completed welds and the adjacent base metal up to a minimum of 12.5 mm (0.5 inch) from both sides of the edge of the deposited weld metal shall be visually

inspected and subjected to NDT in accordance with 4.5. Welds that do not satisfy the acceptance criteria of 3.6.9.1 and 3.6.9.2 shall be repaired in accordance with 3.6.10.

3.6.9.1 Visual Inspection Acceptance Criteria. - The acceptance criteria for the visual inspection of completed welds shall be in accordance with ANSI/AWS D1.1, D1.2, D1.3, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable, as otherwise specified herein, and in accordance with the specified weld classification.

3.6.9.2 NDT Acceptance Criteria. - The acceptance criteria for NDT shall be in accordance with ANSI/AWS D1.1, D1.2, D1.3, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable, for the appropriate NDT technique and weld classification.

3.6.10 Welding Repairs. - All welding repair requirements for pressure vessels shall be in accordance with ASME BPVC, section VIII. Welding repairs requirements for other GSE and related facilities are defined in the following paragraphs.

3.6.10.1 Defect Removal. - Weld and/or base metal containing cracks or cracklike defects shall be removed to sound metal. The use of mechanical means (e.g., grinding, chipping, or machining) to remove defective weld and/or base metal is preferred. After the removal of any metal containing defects, and prior to rewelding, the joint shall be reinspected to ensure that the defects have been completely removed, using the same NDT method and acceptance criteria used to originally detect the defect.

3.6.10.2 Repair Procedure. - The repair welding procedure shall be the same as the original qualified welding procedure, recognizing that the cavity to be repaired may differ in contour and dimensions from the original joint. The completed repair weld shall be subjected to the same NDT requirements and acceptance criteria as the original weld.

3.6.10.3 Repair Records. - The contractor shall prepare and maintain records of all weld repairs and shall make these records immediately available to the procuring agency. No more than two attempts shall be made to repair a weld defect; deviation from this requirement shall be requested in writing to the procuring agency..

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection and Testing.

4.1.1 Responsibility for Inspection and Testing. - The contractor is responsible for the performance of all inspections, tests, and quality control requirements as specified herein. The contractor may utilize his own or any other testing laboratory acceptable to and approved by the procuring agency for the performance of all required destructive and nondestructive testing.

4.1.2 Additional Inspection and Testing. - The procuring agency reserves the right to require additional NDT. This NDT may consist of the same NDT methods originally required, different methods, or a combination of both previously used and new methods. The procuring agency reserves the right to require that coupons be cut from base and/or weld metal for destructive testing. If the applicable acceptance criteria for any additional NDT is not satisfied, or if the coupons subjected to destructive testing do not meet the applicable requirements for strength and soundness, the contractor shall be liable for the cost of the investigation and repair of these defective areas. When coupons are removed from any part of a weldment, the members shall be repaired in accordance with 3.6.10.

4.2 Certified Welding Inspector (CWI). - When a CWI is required for the final visual inspection of completed welds (see 4.5.1), this individual shall be certified as an AWS CWI in accordance with the provisions of ANSI/AWS QC 1. Evidence of this certification shall be made available to the procuring agency.

The CWI will be provided with all WPS's, PQR's, and WPQ's and will verify through this supplied documentation that the WPS was qualified and that the welders/welding operators were qualified (see 3.4). If all other visual inspection acceptance criteria are satisfied but the requirements of 3.4 are not satisfied, the affected weld will not be labeled as having failed visual inspection; however, the CWI shall inform the procuring agency or its designated representative that the requirements of 3.4 were not satisfied.

NOTE

This requirement does not mean that the CWI must witness all qualification testing or that the CWI must inspect the WPS's, PQR's, and WPQ's prior to welding. The procuring agency reserves the right to witness all qualification welding/testing and to review the WPS's, PQR's, and WPQ's prior to the start of welding (see 3.4).

4.3 Qualification of NDT Personnel. - All personnel performing NDT or interpreting NDT results shall be certified in accordance with ANSI/ASNT CP-189. An individual performing NDT shall be a qualified level II or level III individual for the NDT method used, or a qualified level I individual for the NDT method used if under the direct supervision of one of the previously described level II or level III individuals. All qualification levels are as defined by ANSI/ASNT
CP-189. Interpretation of NDT results shall be performed by a qualified level II or level III individual for the NDT method used. NDT personnel certification records shall be made available to the procuring agency.

4.4 Preweld and Welding Inspection. - All preweld and welding inspection requirements (e.g., inspections to verify base metal preparations, proper joint assembly, joint cleanliness, etc.) shall be in accordance with ANSI/AWS D1.1, D1.2, D1.3, D14.1, ASME B31.3, or ASME BPVC, section VIII, as applicable.

4.5 Postweld Inspection.

4.5.1 Visual Inspection. - The contractor shall provide the inspector with the engineering drawings and WPS's showing the size, length, type, and location of all welds. The inspector shall verify that the size, length, type, and location of all welds conform to the requirements of the engineering drawings and this specification, and that no unspecified welds have been added.

4.5.1.1 Structural Welds. - All completed welds shall be subjected to a 100-percent visual inspection in accordance with ANSI/AWS D1.1, D1.2, or D1.3, as applicable. Visual inspections of Class A and Class B welds shall be performed by a CWI (see 4.2).

4.5.1.2 Crane and Other Material Handling Equipment Welds. - All completed welds shall be subjected to a 100-percent visual inspection in accordance with ANSI/AWS D14.1. Visual inspections of welds classified as Class A and Class B shall be performed by a CWI (see 4.2).

4.5.1.3 Piping and Tubing Welds. - All completed welds shall be subjected to a 100-percent visual inspection in accordance with ASME B31.3, with the following additional requirement: all weld profiles shall be in accordance with section 3.6 of ANSI/AWS D1.1, with the exception that the acceptance criteria for undercutting and reinforcement shall be in accordance with ASME B31.3. With the exception of welds designated for Category D fluid service, these visual inspections shall be performed by a CWI (see 4.2).

4.5.1.4 Pressure Vessels. - Visual inspection of completed welds shall be in accordance with ASME BPVC, section VIII.

4.5.2 Nondestructive Testing.

4.5.2.1 Structural Welds. - In addition to the required visual inspection (see 4.5.1), all structural welds shall be subjected to NDT in accordance with the following paragraphs.

4.5.2.1.1 Class A Inspection. - All Class A inspections shall require 100-percent radiographic testing (RT) and either 100-percent magnetic particle testing (MT) or 100-percent penetrant testing (PT) in accordance with ANSI/AWS D1.1, D1.2, or D1.3, as applicable.

4.5.2.1.2 Class B Inspection. - All Class B inspections shall require either 100-percent MT or 100-percent PT in accordance with ANSI/AWS D1.1, D1.2, or D1.3, as applicable. When multipass welds in nonconventional facilities (including equipment) are subjected to a Class B inspection, the root pass, final pass, and each 13-mm (0.5-inch) interval of thickness shall be so inspected. In addition to the normal interpass cleaning requirements for multipass welds, all liquid penetrant materials and/or metal particles shall be removed after each such inspection. For partial joint penetration groove welds and fillet welds in conventional facilities (including equipment), the design engineer has the option of requiring MT or PT of a minimum of 10 percent of randomly
selected production welds; if any of the tested welds are found to be unacceptable, an additional randomly selected 10 percent (minimum) of the production welds shall be tested. If any of the tested welds in the second sampling are found to be unacceptable, then a 100-percent inspection of the remaining production welds is required.

4.5.2.1.3 Class C Inspection. - All Class C inspections require only the visual inspection described in 4.5.1.

4.5.2.2 Crane and Other Material Handling Equipment Welds. - In addition to the required visual inspection (see 4.5.1), all crane and material handling equipment welds shall be subjected to NDT in accordance with the following paragraphs.

4.5.2.2.1 Primary Welds (Class A). - All Class A inspections shall require 100-percent RT and either 100-percent MT or 100-percent PT in accordance with ANSI/AWS D14.1.

4.5.2.2.2 Secondary Welds (Class B). - All Class B inspections shall require either 100-percent MT or 100-percent PT in accordance with ANSI/AWS D14.1. When multipass welds are subjected to a Class B inspection, the root pass, final pass, and each 13-mm (0.5-inch) interval of thickness shall be so inspected. In addition to the normal interpass cleaning requirements for multipass welds, all liquid penetrant materials and/or metal particles shall be removed after each such inspection.

4.5.2.2.3 Secondary Welds (Class C). - All Class C inspections require only the visual inspection described in 4.5.1.

4.5.2.3 Piping and Tubing Welds. - In addition to the required visual inspection (see 4.5.1), all piping and tubing welds shall be subjected to NDT in accordance with the following paragraphs.

4.5.2.3.1 Normal Fluid Service. - All welds classified for normal fluid service shall be subjected to 10-percent random RT in accordance with ASME B31.3; if any of the tested welds are found to be unacceptable, an additional randomly selected 10 percent (minimum) of the production welds shall be tested. If any of the tested welds in the second sampling are found to be unacceptable, then a 100-percent inspection of the remaining production welds is required.

4.5.2.3.2 Severe Cyclic Conditions. - All welds classified as subjected to severe cyclic conditions shall be subjected to 100-percent RT and either 100-percent PT or 100-percent MT in accordance with ASME B31.3. When multipass welds are subjected to PT or MT, the root pass, final pass, and each 13-mm (0.5-inch) interval of thickness shall be so inspected. In addition to the normal interpass cleaning requirements for multipass welds, all liquid penetrant materials and/or metal particles shall be removed after each such inspection.

4.5.2.3.3 Category M Fluid Service. - All welds classified for Category M fluid service shall be subjected to 100-percent RT in accordance with ASME B31.3.

4.5.2.3.4 High-Pressure Fluid Service. - All welds classified for high-pressure fluid service shall be subjected to 100-percent RT in accordance with ASME B31.3.

4.5.2.3.5 Category D Fluid Service. - All welds classified for Category D fluid service shall be subjected to either 100-percent MT or 100-percent PT in accordance with ASME B31.3.

4.5.2.3.6 In-Process Examination for Automatic Gas Tungsten Arc Welding (GTAW). - With the exception of welds designated for high pressure fluid service, an in-process examination may be substituted for the required RT of piping and tubing welds made using a fully automatic GTAW process only. In addition to the in-process examination requirements defined in ASME B31.3, the following additional requirements shall be satisfied:

a. All welds (100 percent) shall be subjected to the in-process examination.

b. The automatic GTAW process parameters shall be strictly monitored and recorded; if these parameters exceed ±10 percent of the optimum values (the optimum values are defined as the values verified/established during the WPS qualification), the affected weld(s) shall be subjected to RT. The process parameters to be monitored and recorded shall include the following:

(1) Arc Current
(2) Time
(3) Pulse Low (amperes)
(4) Pulse High (time)
(5) Pulse Low (time)
(6) Finish Slope
(7) Rotation Delay
(8) Head Speed (rpm)
(9) Shielding and Backup Gas Flow Rate
(10) Arc Voltage
(11) Tungsten Electrode (position, length, bevel, land, arc length)

c. The supplemental NDT required for category M fluid service welds shall be either 100-percent PT or 100-percent MT in accordance with ASME B31.3. The supplemental NDT required for welds classified as subjected to severe cyclic conditions shall be the 100-percent PT or 100-percent MT required by 4.5.2.3.2.

NOTE

All NDT materials (e.g., liquid penetrants, developers, ultrasonic couplants, etc.) that are to be applied to surfaces that will be exposed to oxygen (gaseous or liquid) or hypergols in service shall be compatible with that service fluid. Oxygen compatibility shall be determined by batch testing in accordance with NHB 8060.1; compatibility with hypergols shall also be assessed by testing in accordance with NHB 8060.1. Final approval for use of these materials must be obtained from the procuring agency's appropriate Center Materials Representative.

4.5.2.4 Pressure Vessels. - All NDT shall be in accordance with ASME BPVC, section VIII.

4.5.2.5 Alternate NDT Methods. - In cases where RT is designated for a fillet weld or for a weld that consists of or is part of multiple connections or corner or tee joints of varying thicknesses such that the joint configuration makes it impractical to obtain a satisfactory radiograph, a satisfactory alternate method of NDT shall be proposed by the contractor and approved by the procuring agency. If PT or MT is proposed to be used in lieu of RT, then the root pass, final pass, and each 13-mm (0.5-inch) interval of thickness shall be so inspected. In addition to the normal interpass cleaning requirements for multipass welds, all liquid penetrant materials and/or metal particles shall be removed after each such inspection. In cases where adequate postinspection cleaning is difficult to achieve (e.g., inner lines of vacuum-jacketed systems; intermediate passes of multipass welds in aluminum), PT may be selectively omitted if approved by the procuring agency (e.g., a visual inspection, RT, and a proof test of an inner line in a vacuum-jacketed cryogenic system could be considered sufficient without PT). Also, a PT of just the final pass of a multipass aluminum weld could be considered sufficient. The necessity of selectively omitting PT, as well as the necessity and acceptability of any proposed alternate NDT methods, should be agreed upon by the level III individual (see 4.3) and the procuring agency.

4.5.2.6 Etching for PT. - Weldments that are machined, ground, or otherwise mechanically worked to cause disruption or smearing of the metal surface shall be etched to remove the masking material prior to penetrant application.

4.5.3 Inspection Records. - The contractor shall prepare and maintain records of all visual inspections and NDT procedures and results. These records shall be made available to the procuring agency.

5. PREPARATION FOR DELIVERY

When required, preparation for delivery shall be as specified in the procurement documents.

6. NOTES

6.1 Intended Use. - This specification is intended to be used for the welding of aerospace ground support equipment and related facilities. This specification provides supplementary requirements (e.g., provisions for verification of procedure and performance qualifications; imposing

requirements for NDT; imposing requirements for inspection personnel qualifications; additional welding technique requirements; requirements for material certifications, etc.) to the referenced ANSI/AWS and /ASME industrial codes.

6.2 Data Required in Design Documentation. - The following information shall be provided in the design documentation:

a. Title and number of this specification.

b. Design and inspection classifications of welds (see 1.1).

c. Additional preheating and postheating instructions, if required (see 3.6.1 and 3.6.7).

6.3 Definitions. - The welding terms used in this specification shall be interpreted in accordance with the definitions of ANSI/AWS A3.0. Other definitions are as follows:

a. Conventional Facilities (Including Equipment). - Conventional (institutional or support) facilities (including equipment) are office buildings, laboratory buildings, auditoriums, libraries, warehouses, cafeterias, shops, walkways, utility systems, and other facilities whose structures are characterized by well-established design precedents and loading conditions.

b. Nonconventional Facilities (Including Equipment). - Nonconventional facilities (including equipment) are program-oriented or experimental in nature, and include wind tunnels, test stands, launch complexes, operational or research facilities, towers, and similar special-purpose facilities whose structures are characterized by unusual or inadequately defined loading conditions, a lack of established design precedent, or frequent modifications to support changes in the operational requirements.

Custodian:

NASA- John F. Kennedy Space Center

Preparing Activity:

John F. Kennedy Space Center
Logistics Operations Directorate
Materials Science Division

APPENDIX A

RECOMMENDED ANSI/AWS PUBLICATIONS

It is recommended that the following ANSI/AWS publications be used when developing piping and tubing welding procedures in accordance with this specification:

ANSI/AWS D10.4	Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing
ANSI/AWS D10.7	Recommended Practices for Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe
ANSI/AWS D10.8	Recommended Practices for Welding of Chromium-Molybdenum Steel Piping and Tubing
ANSI/AWS D10.10	Recommended Practices for Local Heating of Welds in Piping and Tubing
ANSI/AWS D10.11	Recommended Practices for Root Pass Welding of Pipe Without Backing
ANSI/AWS D10.12	Recommended Practices and Procedures for Welding Low Carbon Steel Pipe